A Technical Workshop

Long-Distance Pipeline Transport of Dredged Material To Restore Coastal Wetlands of Louisiana

Summary of Proceedings

14 October 2003

Metairie, Louisiana

Compiled by

Lyndell Z. Hales[1], Doyle L. Jones[1]
and
Denise Reed[2]

Sponsored by

U.S. Environmental Protection Agency, Region 6, Dallas, TX
U.S. Army Engineer Research and Development Center, Vicksburg, MS[1]
Western Dredging Association, Gulf Coast Chapter, New Orleans, LA

Co-Sponsored by

U.S. Army Corps of Engineers, New Orleans District
Louisiana Governor's Office of Coastal Activities and R&D Program
Louisiana Department of Natural Resources
Jefferson Parish Department of Environmental Affairs
Plaquemines Parish Port, Harbor, and Terminal District
University of New Orleans[2]
Barataria-Terrebonne National Estuary Program

EPA Project Lead
Beverly Ethridge, EPA Baton Rouge Field Office
Ethridge.Beverly@epa.gov
(214) 665-2151
EPA IAG No. DW-96-950420-01

Table of Contents

Table of Contents (continued)

Acknowledgements

The U.S. Environmental Protection Agency, the Western Dredgers Association and the Corps of Engineers-ERDC wish to thank all the presenters and participants at this conference. The body of work represents tremendous contribution of time, travel and technical sharing on the part of the dredging industry, academia, technology development industries, consultant and local, state and federal public servants.

In particular, we thank Plaquemines Parish President, Benny Rousselle, and Jefferson Parish Environmental Director, Marnie Winter, for the tremendous local support of this conference. These Parishes represent a significant part of Louisiana's coast that is at greatest risk from land loss. These individuals continue their support of innovative and far-reaching strategies to save Louisiana's coastal communities and wetlands. And, without the valuable time and energy of Ms. Mary Rougee, Jefferson Parish, who helped manage registration on the day of the conference, we might have been overwhelmed by the amazing turnout for this important event.

Background [*]

The Mississippi River and it's associated tributaries drain over 1 million square miles and funnel the water and associated sand, silt, and nutrients to Louisiana. Here, over the last 10,000 years, much of southern Louisiana was created by deposition of sediment from the River and it's tributaries as the River flooded and changed course. In its natural condition, the river regularly overflowed its banks across the floodplain, creating land as it meandered back and forth.

In the early 1700s construction of small levees to protect residents from flooding began; however, it was not until the flood of 1927 and subsequent authorization of the Mississippi River and Tributaries Project that integrated river training became dominant. The loss of Louisiana's wetlands began with these levee modifications. Figure 1 shows turbidity induced by the Mississippi River as it flows into the Gulf of Mexico.

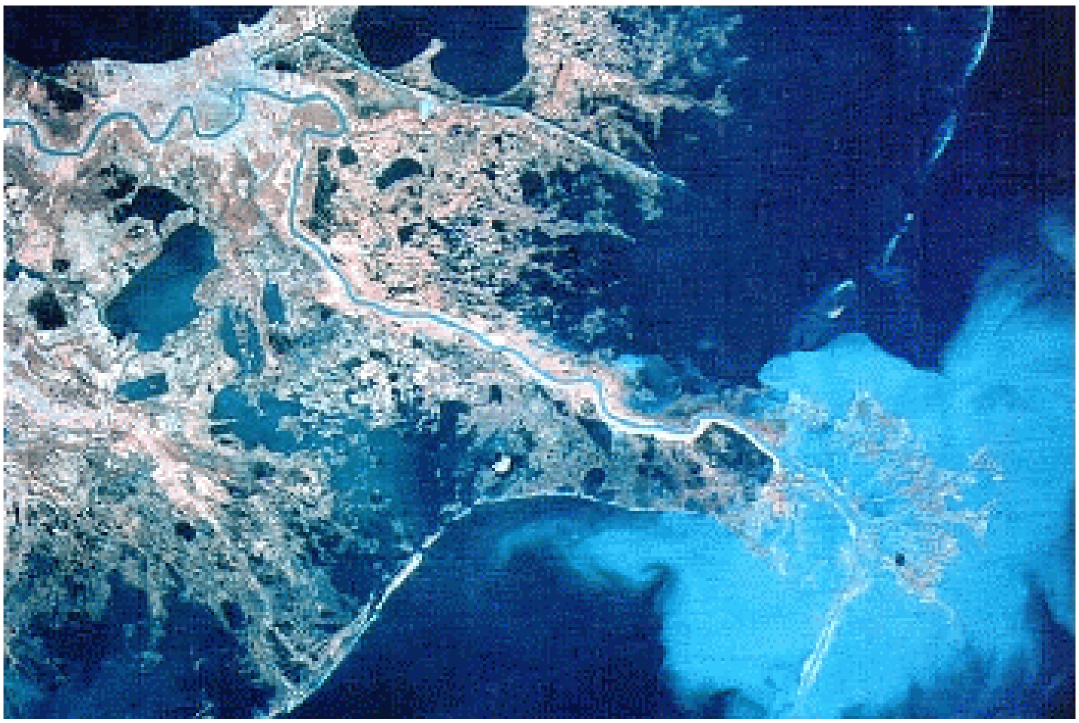

Figure 1. Mississippi River sediment discharge

Since the turn of the century, other factors have played a major role in contributing to wetland losses. The traditional economy of fishing and hunting has been replaced with the extractive economy of oil and gas. Numerous smaller canals were constructed during the same period to shorten the route traveled by commercial and recreational boats. Larger streams have been straightened and enlarged, and waterways have been constructed to connect them, as seen in Figure 2.

[*] Extracted from U.S. Army Corps of Engineers, New Orleans District, Coastal Wetlands Planning, Protection, and Restoration Act (PL 101-646) Program Overview (prepared for White House Interagency Wetlands Working Group, 28 August 1997)

Figure 2. Dredged channels throughout southern Louisiana marshlands

The combination of levees, canals, and waterways has acted synergistically, and has resulted in the gradual loss of wetlands as a result of both direct construction impacts and loss of freshwater inflow, intrusion of Gulf of Mexico salt water, and drainage/flooding of wetlands. These impacts have been further accelerated by geological subsidence and sea level rise. Louisiana's estimated 3.5 million acres of coastal wetlands represent about 30 percent of the coastal marshes in the United States. Unfortunately, Louisiana is experiencing about 90 percent of the annual coastal wetland losses in the lower 48 states. Prior to the 1900s, the coastal area had an overall gain of wetlands; since then, Louisiana has lost about 1.2 million acres of it's coastal wetlands and may well lose another 430,000 acres in the next 50 years. Since the 1970s, the estimated loss rate has been about 35 square miles per year.

Because of the importance of Louisiana's wetlands to the nation, U.S. Senator John Breaux introduced the Coastal Wetlands Planning, Protection, and Restoration Act of 1990 (CWPPRA) (Public Law 101-646, the Breaux Coastal Wetlands Act). CWPPRA is not just a Louisiana program; it is a national program with three key elements: (a) the National Coastal Wetlands Conservation Grant Program, (b) the North American Wetlands Conservation Fund, and (c) the Louisiana Program. The first two elements are administered by the U.S. Department of the Interior. The Louisiana Program is administered by the U.S. Army Corps of Engineers. Details of the CWPPRA with respect to the State of Louisiana may be found at http://www.mvn.usace.army.mil/pd/cwppra_mission.htm and http://lacoast.gov/cwppra/index.htm.

CWPPRA Section 3952 (Priority Louisiana Coastal Wetlands Restoration Projects) directs the creation of "...a process to identify and prepare a list of coastal wetlands restoration projects in Louisiana to provide for the long-term conservation of such wetlands and dependent

Figure 3. Evaluating loss of south Louisiana marshlands

fish and wildlife populations in order of priority, based on the cost-effectiveness of such projects in creating, restoring, protecting, or enhancing coastal wetlands, taking into account the quality of such coastal wetlands, with due allowance for small-scale projects necessary to demonstrate the use of new techniques or materials for coastal wetlands restoration...” .

Purpose of the Workshop

One concept for restoration of the coastal wetlands of southern Louisiana provides for the transport of dredged material by pipeline from the Mississippi River.

In many coastal Louisiana restoration projects, the distances the sediments need to be transported (10-30 miles or more) are greater than those typically constructed by using conventional dredging technology. Most beneficial uses of dredged material projects involve pumping distances of 3 miles or less because booster pumps are not typically used to keep costs reasonably low. Greater pumping distances may be achieved with conventional dredging equipment by the addition of booster pumps, with associated added costs and complexity of such operations being conducted across wide expanse of wetlands. Likewise, dredging/pumping technology is available that has not been previously applied to Louisiana’s coastal problem that may prove useful.

The purpose of the Technical Workshop was to bring together national and international experts in the field of long-distance transport of dredged and other materials by pipeline to help determine the feasibility of transporting dredged material from the Mississippi River to coastal marsh areas of south Louisiana to assist in restoring the wetlands of that region. If this concept is feasible, over time, hundreds of million cubic yards of material may be needed for transport up to 30 miles to enhance the receding coastal marsh area. The Technical Workshop provided guidance for determining if current technology can be adapted, or if emerging innovative methodologies can be developed, to fulfill this critically important mission. Presentations at the Technical Workshop which are summarized in the next section may be found in their entirety at http://lacoast.gov/news/press/2003-09-19a/workshop.htm

The workshop was held at the Jefferson Orleans-South Convention Facilities, Metairie, Louisiana, on 14 October 2003. Two hundred attendees participated in the 1-day workshop. The workshop was funded by the U.S. Environmental Protection Agency, Region 6, Dallas, TX, and organized by the U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS. The workshop was also sponsored by the Western Dredging Association, Gulf Coast Chapter, New Orleans, LA. Co-sponsors of the workshop included U.S. Army Corps of Engineers, New Orleans District; Louisiana Governor's Office of Coastal Activities and R&D Program; Louisiana Department of Natural Resources; Jefferson Parish Department of Environmental Affairs; Plaquemines Parish Port, Harbor, and Terminal District; the University of New Orleans, and the Barataria-Terrebonne National Estuary Program.

Summary of Workshop Proceeding

Benny Rouselle, President of the Plaquemines Parish Council, LA

Mr. Rouselle welcomed participants to the workshop, and stated that he hoped the exchange of ideas by engineers and scientists at the workshop would lead to positive action in rebuilding marshlands in Plaquemines Parish as well as in other regions of Louisiana.

Jeanne Peckham, U.S. Environmental Protection Agency (EPA), Baton Rouge, LA

Ms. Peckham presented "**The U.S. Environmental Protection Agency Commitment to Restoring South Louisiana Marshlands**". The EPA has a long-standing interest in potential for pumping new sediment back into the degrading marshes by using pipelines. The term "new sediment" means sediment that is not currently in the wetland system, or sediment that is not readily available. Sediment bedload of the Mississippi River that is delivered to the Gulf is a prime example of such material. Thirty percent of the marshlands in the United States are in the State of Louisiana. Louisiana experienced 90 percent of the wetlands loss in the lower 48 states during the 1990s. Coastal Louisiana lost 1.2 million acres (1,900 square miles) of land during the 20th century, and lost an average of 34 square miles of land per year (primarily marsh) for the last 50 years. If nothing is done, Louisiana could potentially lose another 430,000 acres (670 square miles) in the next 50 years. There is presently a dramatic progression of coastal wetland loss as evidenced by the estimate for year 2020 (Figure 4). The State of Louisiana is facing an ominous task of restoration.

It is equally important to sustain barrier islands to help reduce tidal forces within marshes. Great volumes of material are required to rebuild barrier islands. EPA has the desire that the results of the workshop will lead to additional critically important tools for rebuilding critical coastal landscape, including coastal marshes and barrier islands.

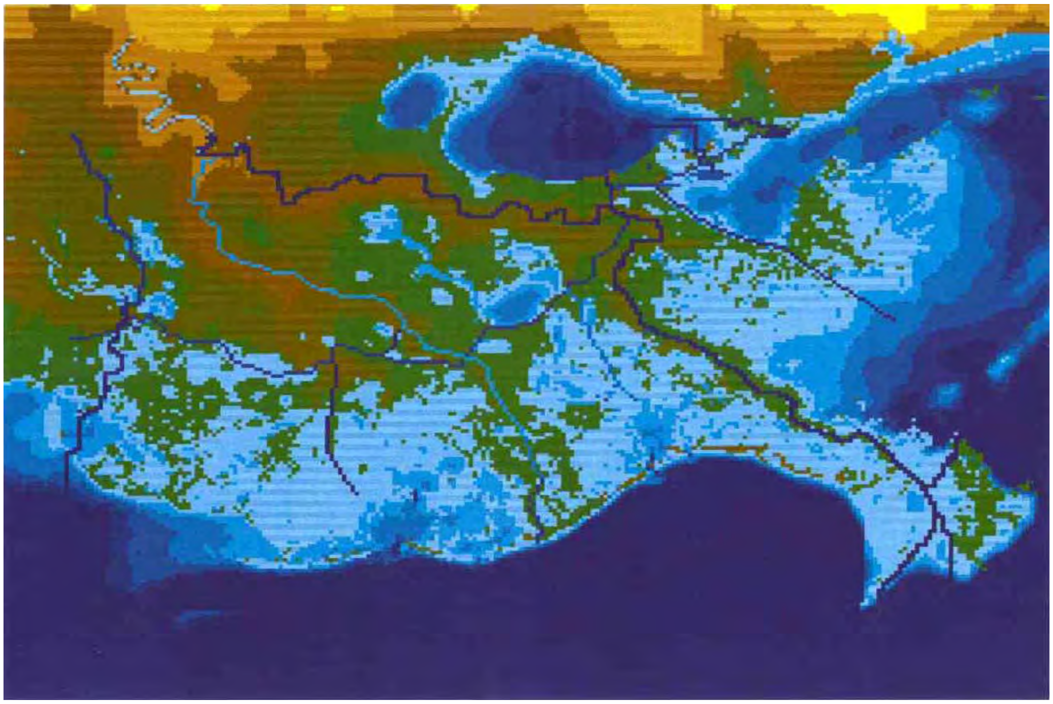

Figure 4. Estimated Louisiana coastal wetlands, year 2020

Len Bahr, Science Advisor to the Governor, Baton Rouge, LA

Dr. Bahr re-emphasized the commitment of the State of Louisiana to restoring coastal wetlands of south Louisiana. He stated that, as a member of the Task Force for implementing the CWPPRA, the Office of the Governor would be fully involved in the funding mechanism for assuring that state resources become available for cost-sharing this critically important endeavor. Mr. Bahr was pleased that at least half the audience consisted of new faces to the wetlands restoration community. This was especially good news because this workshop was truly the first of its kind where industry and restoration folks were paired in such a technology exchange.

Clark McNair, Workshop Facilitator, ERDC Technical Consultant, Vicksburg, MS

Mr. McNair pointed out that the range of options for the Louisiana coast includes everything from totally natural to totally man-made. The optimum solution lies somewhere between these extremes and must still be determined. It is essential to locate and characterize the source sediments and to match the source characteristics to the destination needs. If a long distance delivery system is required to transport the material to its destination, then such a system must be planned, engineered, and developed according to the flow chart of Figure 5.

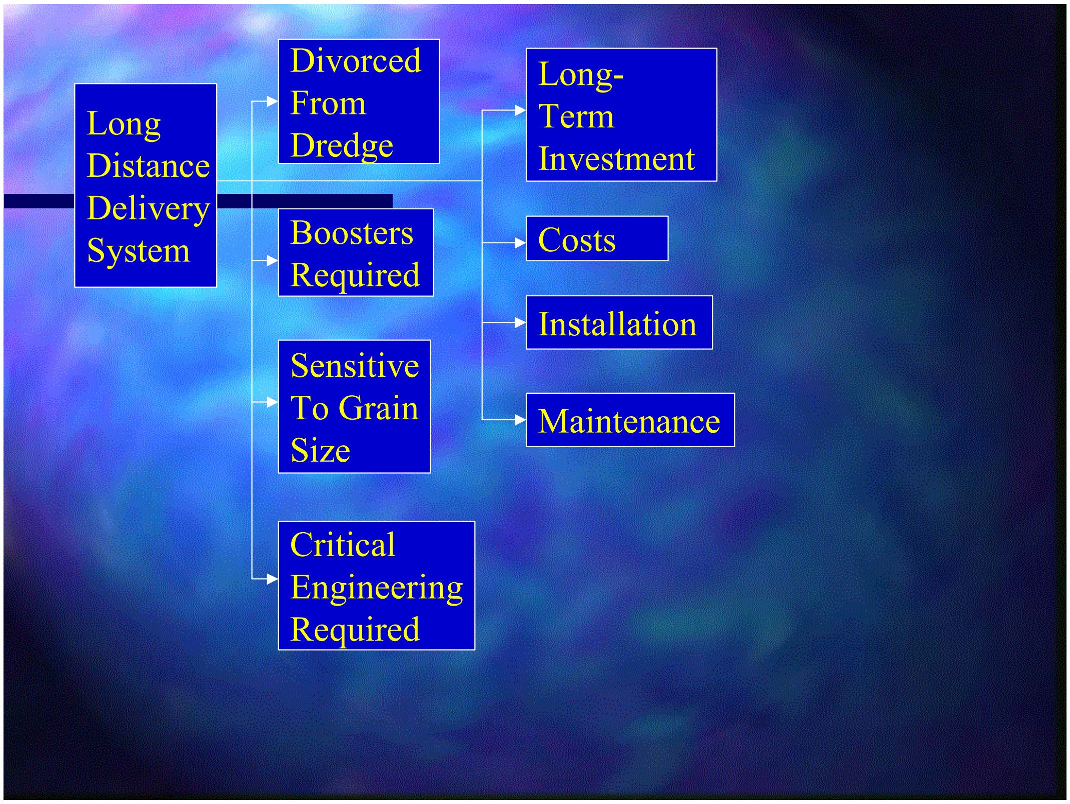

Figure 5. Flow chart for long-distance delivery system for dredged material

Edmond Russo, U.S. Army Corps of Engineers, New Orleans District, New Orleans, LA

Mr. Russo presented "**Innovative Dredging Techniques for Re-attaining Ecosystem Sustainability in Coastal Louisiana: Concept Development Initiative**." Freshwater and sediment diversions address needs for estuarine gradient management and vertical accretion, and are valuable for re-attaining sustainability. Dredging approaches can provide results in the near term. Dredging restoration should be used in concert with diversions, and may provide creative new principles and practices for wetland restoration and for barrier islands at high-energy critical states.

Sustainable and suitable material sources for marshland and barrier island restoration include the renewable Mississippi River resources and offshore borrow areas (Ship Shoal and others). Lessons previously learned include barrier island restoration should be wider, not higher. Leverage nature for sediment distribution, including conveyance channels and littoral drift. There is an estuary/barrier island interrelationship for the systems health. Smaller bays and more interior wetlands will produce more resilient islands. There is considerable investment return with increased sediment scour resistance.

Design an erosion-resistant base for barrier islands to weather extreme events at a critical state. Design for limited incipient motion of sand particles, and design for sand particle settling to minimize losses during extreme events. Wetland design considerations include (a) diking

Figure 6. Barrier island and adjacent marshland

modes (confined, semi-confined, or unconfined), (b) placement modes (wetland creation/nourishment or thin layer), and the target wetlands (instant or enduring). Material to build barrier islands should be sand, while material to build wetlands will include sand and smaller diameter material. Material handling considerations include single-handling or multiple-handling/stockpiling/re-distribution. Material input to the system may be steady- or unsteady-state.

The excavation system selection includes (a) cutting efficiency, (b) sediment size hydraulic sorting (immediate discharge of unwanted sizes, retention and conveyance of desired sizes), and (c) slurry solids intake maximization. Pump and pipeline system configuration includes (a) pump efficiency maximization (impeller design, pump casing design, and number, size, and positioning), and (b) pipeline system sizing (intake-to-discharge diameter ratio, discharge line length and valving, and pipeline materials composition to minimize wear and friction head losses). The prime mover system considerations include (a) minimum energy consumption, (b) maximum power delivered, and (c) alternative energy sources (diesel, diesel-electric, electric, natural gas, hydrogen-fuel technology).

Gregory Miller, U.S. Army Corps of Engineers, New Orleans District, New Orleans, LA

Mr. Miller presented "**Dredging to Construct Coastal Wetlands in Louisiana under the Breaux Act and Other Programs**." The Breaux Act was enacted in 1990 as a Coastal

Wetlands Planning, Protection and Restoration Act (CWPPRA). The act provides federal funds for coastal wetlands restoration projects in Louisiana (70 percent) and other states (30 percent). The funding level is between $30 million and $55 million per year for coastal restoration work in Louisiana, and is currently authorized through 2009. To date, 142 projects have been authorized to restore 130,000 acres at a total cost of $1.3 billion. Techniques and project types undertaken include (a) confined cell wetland creation, (b) unconfined deposition for wetland creation, (c) barrier island restoration, and (d) diversion channel construction.

The Breaux Act has constructed 15 projects utilizing hydraulic dredging for habitat restoration. Twenty-three million cubic yards have been hydraulic dredged, and 3,100 acres have been created or benefited at a cost of $100 million. These projects include (a) Bayou LaBranche wetland creation (1994, 2.5 million cu yd, 203 acres, 70 percent land and 30 percent water), (b) Atchafalaya sediment delivery (1998, 720,000 cu yd, 185 acres, marsh created during construction as part of larger plan to reopen two river passes), (c) Big Island mining (1998, 3.4 million cu yd dredged, 922 acres, marsh created during construction as part of larger plan to redirect river flow), (d) Barataria Bay Waterway wetland restoration (1999, 75,000 cu yd dredged, 9 acres, resulted in shallow open water not marsh in cell but overflow material enhanced adjacent wetlands), (e) Lake Chapeau project (1999, 500,00 cu yd, 260 acres, problems with dikes, borrow material, and access corridor, positive end result), (f) West Belle Pass headland restoration (1998, 1.75 million cu yd, 184 acres, problems with containment dikes and access corridor damage), (g) dustpan dredge demonstration project (2002, 220,000 cu yd, 20 acres, operational experiment rather than marsh creation project), (h) Holly Beach sand

Figure 7. Sabine Refuge marsh creation

management project (2002, 1.75 million cu yd, 300 acres of beach and dune habitat restored, only pure beach nourishment project built by CWPPA), (i) Sabine Refuge marsh creation (2002, 1 million cu yd, 200 acres, post-construction dike degradation, plantings, and trenasse cutting), and (j) West Bay sediment diversion (under construction, 1.6 million cu yd, 100 acres to be created during construction of river diversion channel).

CWPPRA has constructed four barrier island dredging projects, dredging 14 million cu yd to restore more than 700 acres of island habitat. Site conditions are very challenging, and borrow material quality is more critical. Agency and academic consensus is lacking in design details and biological goals. Storm durability of restored islands has been fair. Additive features such as plantings and sand fencing have shown mixed results in storms.

Future CWPPRA projects in the engineering and design stage include (a) four marsh creation projects (dedicated dredging on Barataria Basin landbridge, Little Lake shoreline protection dedicated dredging, Mississippi River sediment delivery system, and Mississippi River sediment trap) and six barrier island projects (east/west Grand Terre Islands restoration, New Cut dune and marsh restoration, Pass Chaland to Grand Bayou Pass barrier shoreline, Raccoon Island shoreline protection/marsh creation, Ship Shoal (Whiskey west flank restoration), and Timbalier Island dune and marsh creation).

Other programs in Louisiana using dredged material to construct wetlands include (a) maintenance dredging beneficial use (created 7,000 acres since 1985), Continuing Authorities Program Sec. 204 and Sec. 1135 projects), (b) State of Louisiana small dredge demonstration project, and (c) private construction and mitigation.

Lessons learned include the following: (a) Clear project goals must be formulated, and design efforts should be goal-oriented. (b) Containment versus confined disposal should be determined based on whether it is desired to have the material flow to other areas or be restrained from entering other habitats. (c) Sediment characteristics must be compatible between the borrow area and the disposal region. (d) Wetland creation site characteristics must be ascertained for the present and for many years into the future. (e) It is critical to manage the construction properly, and to enforce all contract specifications.

Richard Smith, Weeks Marine Incorporated, Kenner, LA

Mr. Smith presented "**Current Dredging Industry Technologies Pertaining to Pipeline Transport**." Beneficial uses of dredged material can be divided into (a) coastal restoration (wetland creation, barrier island restoration, beach nourishment, bird island development, maritime forest/chenier ridge development, and sub-tidal habitat enhancement), and (b) development (roadway base creation, marinas/residential communities, and industrial waterside facilities).

Placement modes are (a) confined, (b) semi-confined, and (c) open water. Placement measures utilize (a) existing emergent land features, (b) earth dikes, (c) rock enclosures, (d) geotubes, and (e) access channels.

Figure 8. Barrier island restoration with dredged material

Sources of material in coastal Louisiana include (a) dedicated borrow areas (Mississippi River, offshore Gulf of Mexico, and interior bay/lake bottoms, and (b) channel maintenance materials. Dredged material considerations include (a) consistency (sand, silt, clay), (b) disposition (virgin or maintenance material), and (c) dredgeability (silts and clays may be unconsolidated fluff or consolidated true bottom material, sands may be loose or hard packed).

Material may be (a) single-handled, or (b) re-handled. For material single-handling, four items must be considered; (a) excavate, and direct pump via pipeline, (b) pump with power-boosters, (c) pipeline acquisition/assembly/maintenance, and (d) spread material as fill advances. For material re-handling, four items must be considered; (a) excavate, stockpile, and deliver with large pipeline, (b) excavate, and deliver with hoppers, (c) excavate, and deliver with scows, and (d) excavate, stockpile, re-slurry, and discharge into final area.

Types of dredges include (a) mechanical buckets, (b) hoppers, and (c) cutterhead pipelines. Parts of the cutterhead pipeline system include (a) suction (dustpan, cutterhead for less than 75 ft, and open suction for deep dredging), (b) pumps (long line implies high psi pumps, large discharge diameter implies high horsepower), and (c) pipeline.

Production factors include (a) grain size, (b) pipeline diameter (head loss per foot of line goes down as pipeline diameter increases, horsepower per foot of line goes up as pipeline diameter increases), (c) pipeline length (for a fixed psi, discharge distance varies with pipeline diameter), and (d) horsepower (for a fixed horsepower, discharge distance varies with pipeline diameter). Any horsepower left over after pumping the water-filled pipe can be used to pump dredged material.

Bid competitiveness will be dependent on (a) well-defined existing conditions, (b) long lead times and contract durations, and (c) clear measurements and payment criteria. Industry interest will be a function of size and frequency of available work.

Two concept layouts for renourishing Plaquemines Parrish with (a) dredge alone, (b) dredge and one booster pump, and (c) dredge and two booster pumps, are shown below.

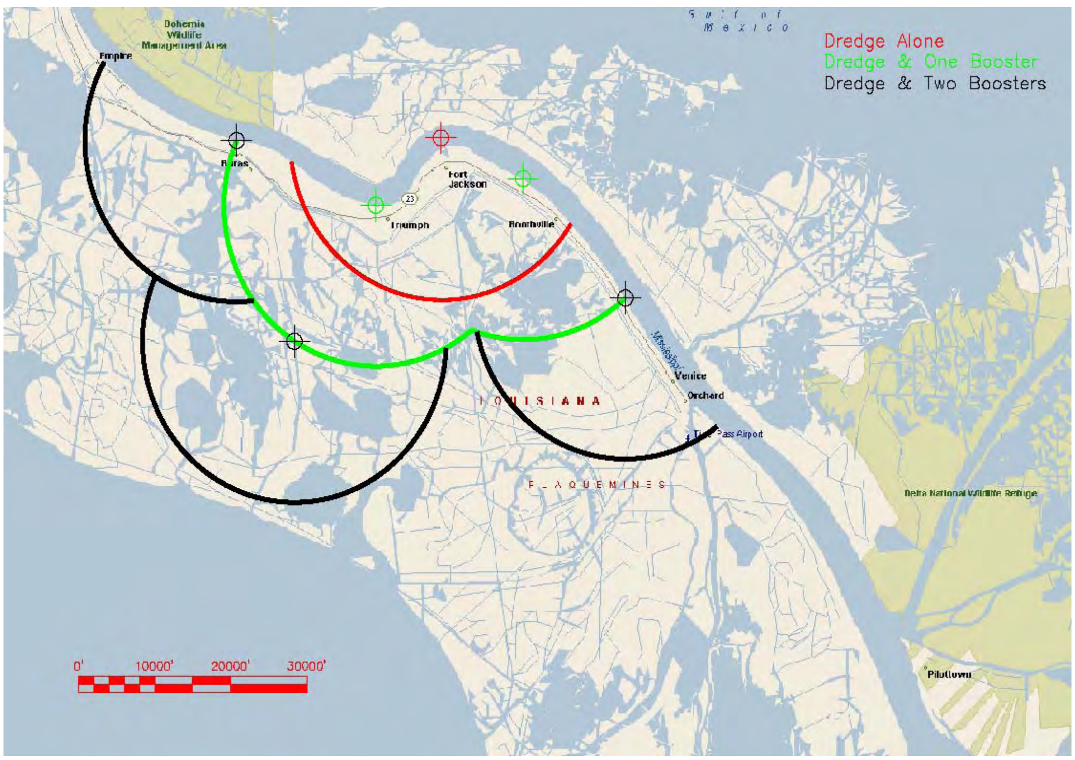

Figure 9a. Concept 1 for renourishing Plaquemines Parrish

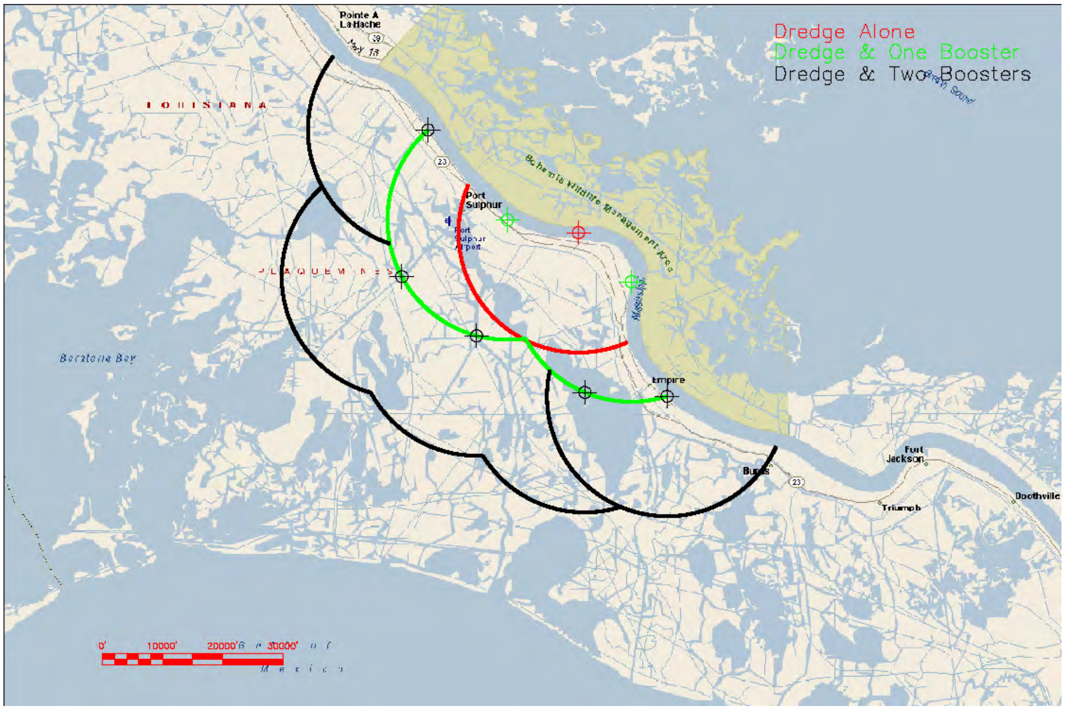

Figure 9b. Concept 2 for renourishing Plaquemines Parrish

Mead Allison, Tulane University, New Orleans, LA

Dr. Allison presented "**On-going Survey of Sediment Availability in the Lower Mississippi River**." The 1999-2002 Project pertained to seasonal storage of fine-grained sediments on the Mississippi River bed. Three field sites were investigated; (a) Audubon Park at New Orleans, (b) English Turn immediately downstream from New Orleans, and (c) Venice near the Mississippi River delta. The study investigated the relationship with discharge (timing), mechanism of formation, lateral and temporal extent, and character of the sediments. Data collection included (a) acoustic (multi-beam bathymetry, side-scan, and CHIRP) (b) water column (CTD and Turbidity), and (c) cores and grab samples. The suspended sediment load/concentration is non-linear with discharge.

Estuarine storage thickness can be mapped acoustically. At the Venice site (Figure 10), it was determined that (a) total river area = 17.8 km^2, (b) storage area = 7.8 km^2 (44 percent), (c) storage thickness = 0.25-2.50 m, (d) total Venice storage = 6.1 x 10^6 tons, and (e) Venice + downriver storage = 1.1 x 10^7 tons. This is approximately 10-15 percent of the total suspended load. Estuarine storage location closely follows the extent of the saline layer. Estuarine sediment storage accumulation is rapid, and remains throughout the low discharge phase. The estuarine storage rapidly remobilizes during rising discharge peaks.

Freshwater low discharge storage was investigated at English Turn (Figure 11) with water depths from 0-20 m. Freshwater storage can be recognized by the grain size. Here it was

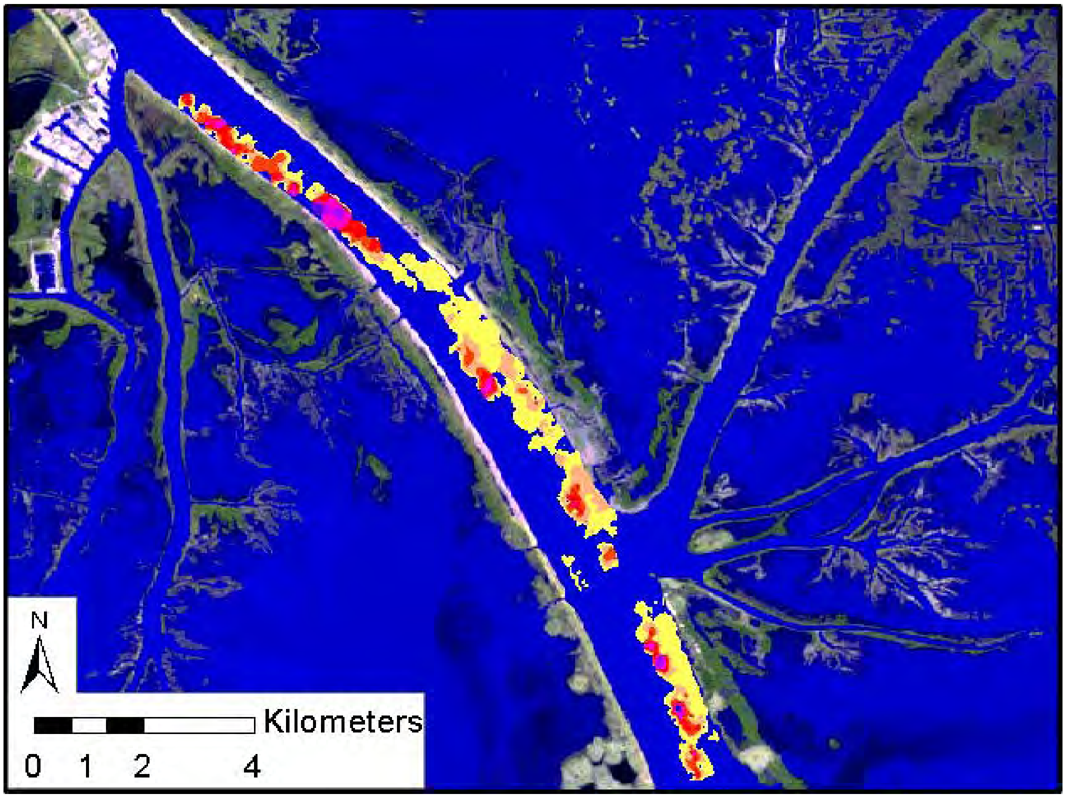

Figure 10. Venice field site

Figure 11. English Turn field site

determined that (a) total river area = 7.43 km^2, (b) west bank storage = 2.13 km^2, and (c) east bank storage =0.51 km^2. The sediment was in a 20-cm-thick layer with a density of 1.3 gm/cm^3 saturated. The total English Turn storage was found to be 4.2 x 10^5 tons. The total lower river storage from mile 181 to mile 13 was found to be 1.4 x 10^7 metric tons (low discharge). This is approximately 10-15 percent of the total suspended load, and is distributed over 59 percent of the river bottom.

The 2003-2004 Project 1 pertains to bed image velocimetry of the Mississippi River bedload sand transport at the Audubon Park site (Figure 12). Sand is also transported in suspension as well as in bedload. Project 2 pertains to assessing quantity and quality of sand available in the lower Mississippi River channel for coastal marsh and barrier island restoration in south Louisiana. Project 2 is being conducted at the Venice site.

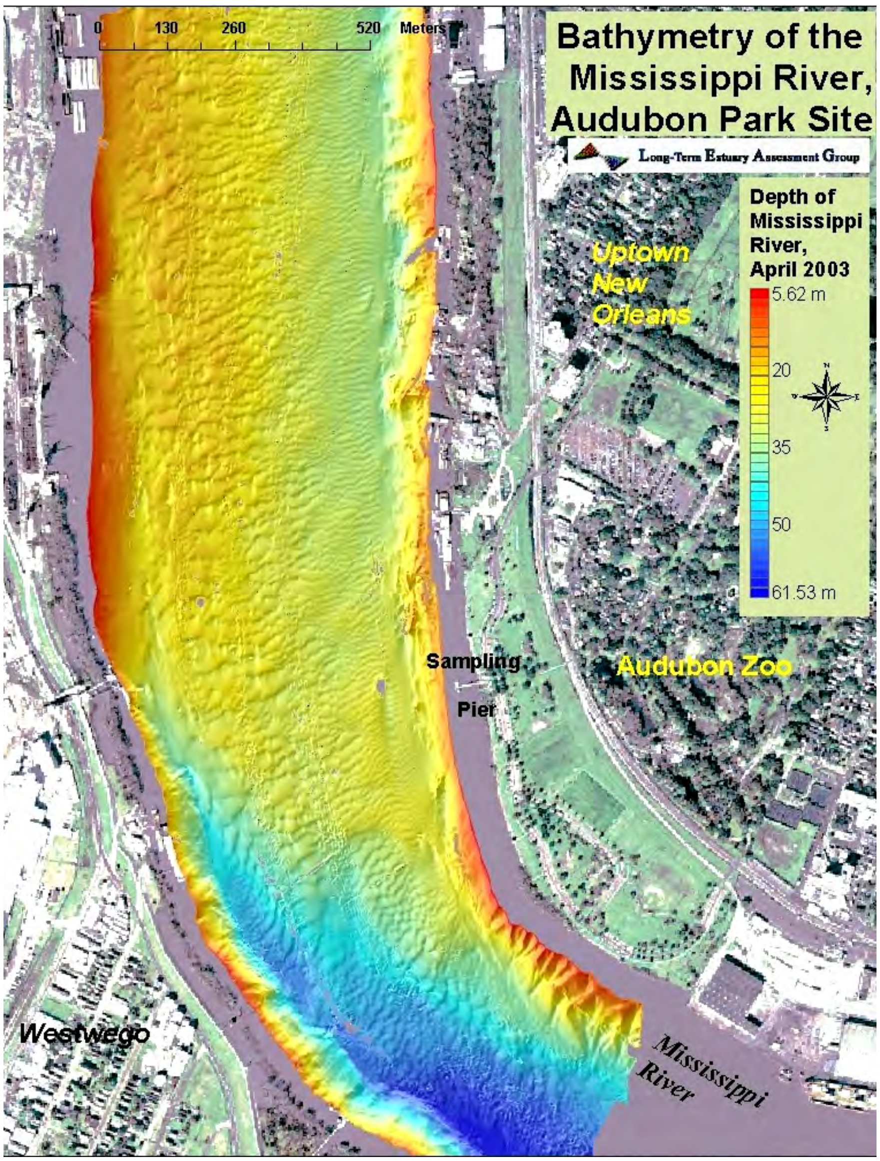

Figure 12. Audubon Park field site

Based on mapped spatial distribution of sand deposits with respect to water depth and river mile in this on-going investigation by Tulane University, optimal locations will be determined for (a) dredge operations or inlet pipes for Barataria barrier island littoral replenishment, and (b) future river diversion structures to capture sand, and develop the appropriate design criteria for such structures.

Robert Randall, Director of the Center for Dredging Studies, Texas A&M University, College Station, TX

Dr. Randall presented "**Fundamental Principles of Slurry Pumps and Sediment Pumping**." The design and structure of large centrifugal dredge pumps of size sufficient to perform the dredging necessary to restore south Louisiana were described. Booster pumps may be needed for long pipelines, and placement is critical. Different booster pump configurations were also discussed. Potential problems with dredge pumps were considered, including pump cavitation, wear, lining, and clearance. Critical velocity of slurry material was also discussed.

Pump cavitation occurs when liquid pressure is reduced below water vapor pressure, causing vapor filled cavities. Dredge pump cavitation results in noisy operation, reduced efficiency, vibration, and damage to the pump. Cavitation effects are commonly characterized with the term "net positive suction head". Cavitation effects on dredge pump performance are usually determined experimentally. A ladder pump may be needed to avoid cavitation.

Figure 13. Large centrifugal dredge pump

Figure 14. Jackup booster pump arrangement

Dredge pumps are designed to allow large particles to pass through the pump (e.g., 6-in-diam. spheres). Dredge pump clean-out capability is usually located at the suction intake. Most dredge pumps are lined to minimize abrasion and wear. Wear is a function of design, material hardness, slurry concentration, size, velocity, weight of solids, median grain diameter, and angularity. Wear is proportional to the velocity cubed (V^3). The optimum operating point of a dredge pump can be determined by the system head curve superposed on the pump characteristics curve.

The pipeline may be either steel or plastic (steel is usually preferred), and can be either floating, on shore, or submerged (depending on the site-specific situation). The sediment-water flows within the pipe may be either (a) settling flows (sand and gravel), or (b) non-settling flows (fine-grained materials such as silts and clays). Flow within the pipeline may occur as a homogeneous suspension with particles evenly distributed vertically throughout the water mass. Heterogeneous flow occurs when all solids are in suspension but a higher concentration occurs near the bottom of the pipe. Flow can also occur within a pipeline as a moving bed or saltation (with or without suspension). Finally, flow can occur with a stationary (fixed) bed.

Critical line velocity varies with pipeline diameter and nature of the material. Critical velocity of the slurry in the pipeline is that velocity below which material can settle to the bottom of the pipeline and cause blockage. The greater the particle size the greater the line velocity necessary to prevent blockage. Critical line velocity is also important for pumping hard clays since such materials tend to ball up (in some cases 12 inches in diameter) and can plug a line easily if velocity is too low.

Joseph Suhayda, Louisiana State University, Baton Rouge, LA

Dr. Suhayda presented "**Use of Pipeline Conveyed Sediments to Create Wetlands**." In 1998, after extensive studies and construction of a number of coastal restoration projects accomplished under CWPPRA, the State of Louisiana and the Federal agencies charged with restoring and protecting the remainder of Louisiana's valuable coastal wetlands adopted a new coastal restoration plan "Coast 2050: Toward a Sustainable Coastal Louisiana" (known as Coast 2050). The underlying principles of the new plan are to restore and/or mimic the natural processes that originally built and maintained coastal Louisiana. For the first time, solutions were proposed to address fundamental ecosystem needs to prevent the loss of this natural treasure. By implementing the plan's regional ecosystem strategies, it is envisioned that a sustainable ecosystem will be restored in coastal Louisiana in large part by utilizing the same natural forces that initially built the landscape. This necessitates basin-scale action to restore more natural hydrology and sediment introduction processes. The plan sub-divides Louisiana's coastal zone into four regions with a total of nine hydrologic basins. The plan proposes ecosystem restoration strategies that would result in efforts larger in scale than any that have ever been implemented in the past. Hundreds of million cubic yards of sediments conveyed by pipeline will be necessary to accomplish this monumental task.

Strategic objectives of Coast 2050 are to (a) sustain a coastal ecosystem with the essential functions and values of the natural ecosystem, (b) restore the ecosystem to the highest practicable acreage of productive and diverse wetlands, (c) and accomplish this restoration through an integrated program that has multiple use benefits (benefits not solely for wetlands, but for all the communities and resource of the coast). Strategic goals of Coast 2050 are to (a) assure vertical accumulation to achieve sustainability, (b) maintain estuarine gradient to achieve diversity, and (c) maintain exchange and interface to achieve system linkages. The Bayou La Branche wetland project converted 300 acres of open water to land. This project required 2.7 million cubic yards of material, and 4 months to construction time at a cost of $3.5 million.

The use of formerly-used pipelines as a means of transporting material to the marsh was discussed. This would be an industry in-kind contribution to coastal restoration. The system of pipelines is statewide, interconnected, and high density in wetlands and along the coast. Excess capacity of pipelines exists as oil and gas fields are depleted, although most unused pipelines may not be legally abandoned. Abandoning a pipeline eliminates removal impacts and associated costs, but also entails legal ramifications. Thus, the use of existing right-of-ways for formerly-used pipelines to construct a new system of pipelines for long-distance transport of dredged material to restore coastal Louisiana may be feasible.

At present, the estimated loss rate of coastal wetlands is about 12,000 acres per year. Thus, a rebuilding objective to maintain the status quo would be 12,000 acres per year. However, to reclaim previously lost wetlands, a total objective of 24,000 acres per year could easily be envisioned as being necessary. This would be equivalent to 80 Bayou La Branches being constructed each year.

The wetland rebuilding strategy is to use pipeline conveyed sediments and create a general permit type design for wetland types. The strategy would provide industry with priority locations, rights of way, and sediment source information. The objective is to build 80 lowest cost Bayou La Branches each year, based upon competitive bids, so that by year 2090 the Louisiana coastline would be restored to it's original configuration (Figure 15). Diversions and sediment renourishment would be managed by monitoring and ecosystem modeling.

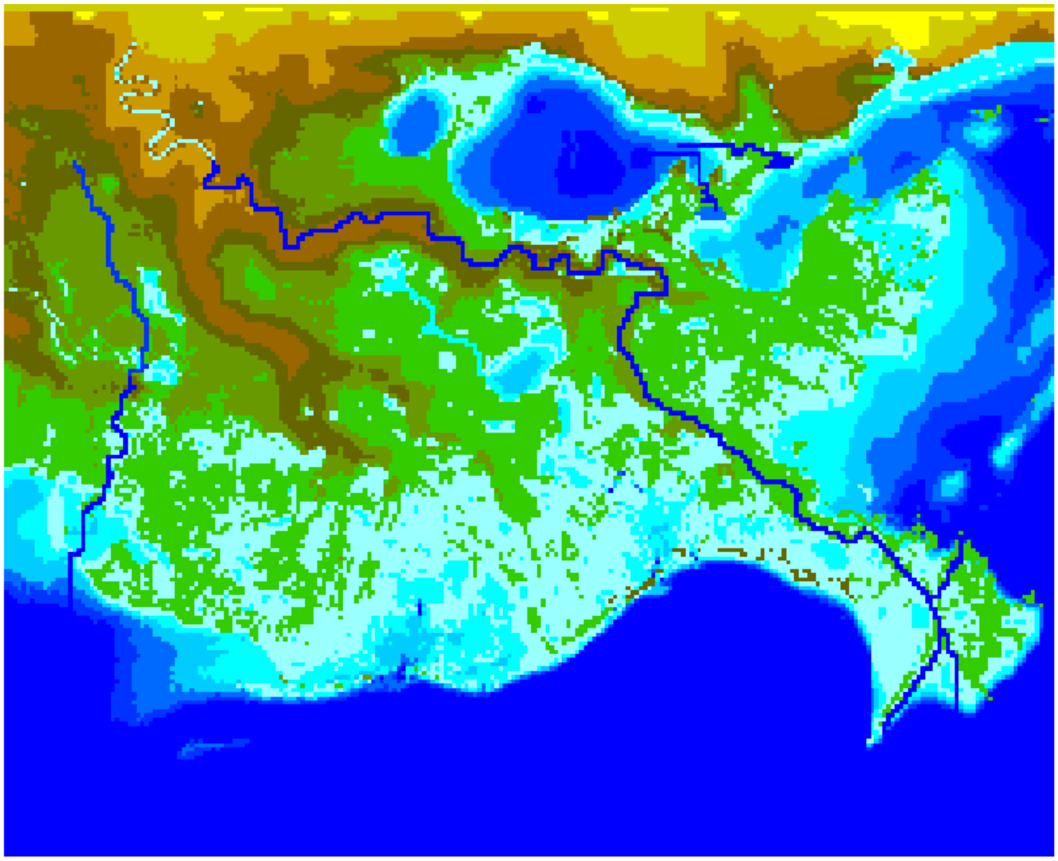

Figure 15. Envisioned rehabilitated Louisiana coastline, year 2090

Willem Vlasblom, Delft University, Netherlands

Dr. Vlasblom presented "**Long-Distance Pipeline Transport of Dredged Material, and the Betuwe Route from Rotterdam Harbor to the German Border: Design of Pipeline, Booster Pumps, and Results.**" Items discussed included (a) difference in operation between a dredge pump only and a dredge pump with a number of boosters, (b) boundary conditions for the design of the pump-pipeline system, (c) problems to be expected when pumping heterogeneous flows, and possible solution for the problems, and (d) the Betuwe Route, and (e) conclusions.

From the operations point of view, there is hardy any difference between pumping with one pump or with more than one pump, as long as the velocity is sufficiently above the deposition limit. However, the pumps should be designed for the same operation capacities. The characteristics of pumps in series can easily be determined by superposition of the manometric pressure and the required power at a given capacity from the pumps involved.

Boundary conditions for the location of boosters are (a) pressure at the suction side should be at least 1 bar, (b) maximum pressure at the discharge side is determined by allowable pressure in the pump shaft seal, and (c) accessibility to the booster. With a maximum allowable pressure pump seal of 30 bars and an allowable manometric head of 7-9 bars because of wear reasons, 3 pumps could be put directly in series. The distance between boosters for 0.25 mm sand would be about 7 to 9 miles, depending on concentration when the working range is close to nominal values.

When operating a centrifugal dredge pump and pipeline system near the deposition limit of heterogeneous flow, amplifying of the initial density variations from the dredge pump may occur, and difficulties as engine overload could arise with even shutdown of the booster engines. These density variations are caused by non-equilibrium between erosion and sedimentation between a bed and the suspended layer of the material being dredged, resulting in slip variation between the two phases of the slurry. This results in high and low density areas in the pipeline. Thus redundancy should be built into the system by application of two or more pumps at a booster station.

The Betuwe Route project (Figure 16) was the construction of a 2-track railway bed by centrifugal hydraulic dredge and boosters for up to approximately 100 miles for freight transport from the port of Rotterdam to the German border. Approximately 3.2 million cubic meters of

Figure 16. Betuwe Route project pipeline

Figure 17. River Maas borrow area

Figure 18. Barge booster station “Bevert”

sand were transport by pipeline, of which about 0.9 million cubic meters were barged across a river and re-handled. A dredge with 3 pumps, and 4 booster stations with 1 pump each were installed along a pipeline of mostly 700 mm diameter pipe. The booster stations were remotely controlled from the dredge. Pump interruption was a major consideration. Vertical and steep inclines were avoided because of high probability of system blockage if the system should shut down for any reason. Starting the pumps with clear water was a series one-by-one operation, beginning at the dredge pump. Actually dredging began when the flow velocity throughout the system reached its required value. Clearing a blocked pipeline would be virtually impossible. The system was shut down by ceasing the dredging process, and pumping clear water until all dredged material had been discharged from the pipeline. All pumps were then sequentially stopped opposite from the starting procedure.

The mean velocity of the slurry during operation of the Betuwe Route project was between 4.5 and 4.9 m/sec producing a mixture flow between 1.49 and 1.63 m^3/sec. The total pressure provided by all pumps was 40-45 bars. The highest local pressure was just behind the 3rd pump on the dredge of about 17 bars. The lowest pressures were in front of the booster pumps of about 3-5 bars. The pressures just behind the boosters were 9-13 bars. The pressure in the pipeline never fell below atmospheric pressure (1 bar). The flow was partially stratified, as a portion of particles occupied the bed. The pipeline was operated around the deposition limit velocity. There was a stationary bed at velocities below approximately 4.7-4.8 m/sec. The presence of this stationary bed led to an interaction between the bed and the suspension stream that resulted in an aggregation process. The largest density peaks developed at the lowest mean velocities in the pipeline. The density peaks may grow to very dense masses if the velocity remains low for a long time.

To avoid aggregation, design the system for an operation velocity sufficiently above the deposition limit if heterogeneous flows can be expected. In homogeneous flows, there is equilibrium between settling and dispersion of the particles. Transport of dredged material by pipeline over distances of 30 miles or more is certainly possible. When a heterogeneous flow can be expected with operations near the deposition limit, amplifying of the initial density variations may occur and difficulties such as engine overload and even shut down can arise. Redundancy in the system is advisable, with multiple booster pumps at a booster station. Steep inclined and vertical sections in pipelines must be avoided to make easy shut down possible.

Van Cook, Louisiana Department of Natural Resources, Baton Rouge, LA

Mr. Cook presented "**Findings of a Previous Investigation of the Feasibility of Using Abandoned Pipelines for Moving Dredged Material in Coastal Louisiana.**" In 1992, Louisiana Senate Resolution No. 164 was passed which directed the Louisiana Department of Natural Resources (DNR) to develop and implement a pilot project to determine the feasibility of using abandoned pipelines for sediment diversion in the coastal restoration program. The resolution stated that many such abandoned pipelines existed, and that the pipeline owners were willing to work with the state to allow use of pipelines for sediment diversions. The consulting firm of Pyburn & Odom, Inc., was retained to provide engineering services for the study. Task 1 of the study was to determine the **potential** feasibility of using abandoned oil and gas pipelines for sediment diversion to marshes. If Task 1 were found to be feasible, then Task 2 would be to prepare a conceptual design and an estimated cost for a pilot project to demonstrate **practical** feasibility. Canvassing the oil and gas companies for location of abandoned pipelines was not a task for this study.

Pipeline capacities were evaluated as to (a) lengths (5, 14, and 30 miles), (b) diameters (8, 12, 16, and 24 in.), (c) slurry concentrations (10, 20, 30, and 40 percent solids), (d) slurry composition (lower Mississippi River sand with median grain size of 0.18 mm), (e) pumping capacity (operating velocities at least 10 percent above minimum velocity to establish flow with a heterogeneous mixture; booster pumps placed at 1-mile intervals), (f) allowable pressure (design operating pressure of 165 psi (310 ft of pressure head), and project pipe erosion rates (highest on pipe bottom at 1/8-in. of wear per 500,000-2,000,000 cubic yards of dredged material pumped. The sediment source was assumed to be the lower Mississippi River. It was also assumed that sediment would be placed in the marsh to 9 ft of height (including compaction, settlement, and sediment loss) in 3 ft of water depth.

Three pipeline system scenarios were considered; (a) direct connection where the dredge discharge pipe could be connected directly to an abandoned pipeline, (b) indirect connection where an intermediate pipeline would be necessary to connect the dredge discharge pipe to an abandoned pipeline, and (c) band storage and barge or truck transport from the dredge to an abandoned pipeline. All systems considered involved many other factors such as (a) legal (servitude, ownership, liability), (b) environmental (contaminants), and (c) regulatory (permits).

The study determined that the use of abandoned pipelines to transport sediment to create or restore marshes in coastal Louisiana is **potentially** feasible. A pilot study was undertaken to determine **practical** feasibility. A conceptual design was considered at Tiger Pass near the Tidewater facility using abandoned Exxon 8-in.-diam pipeline. Dewatering and re-slurrying of the dredged material was required. The estimated cost was found to be $ 1 million to restore 10 acres of marsh. While abandoned pipelines do exist, no pipelines were found to be unconditionally available. Furthermore, the pipelines that were found to be even conditionally available were of less than optimal size. Most were in the 8-12-in. diam size, far less than an optimal diameter for transporting large quantities of dredged material. The use of abandoned pipelines was found to be **potentially** feasible, but **practical** feasibility was not proven. Cost per acre was exceedingly high, and abandoned pipelines of an appropriate size and in the appropriate location are believed to be essentially non-existent.

Graeme Addie, Georgia Iron Works Industries, Grovetown, GA

Mr. Addie presented "**Slurry Pipeline Design, Testing, and Practice**." A slurry pipeline design is based on knowledge regarding the range of values which pertinent parameters will be required to experience. It is necessary to know whether the concentration is fixed or can be varied, whether the pipeline diameter can be varied, and whether the slurry is a settling or non-settling type. Thus, it is necessary to know a prior how much the slurry size, type, concentration, etc., can vary or change during the pumping operation.

Solids transport rate for different pipe diameters, velocities, and concentrations can be ascertained from nomographs developed by laboratory testing. The demarcation between settling and non-settling slurries for various particle diameters is also obtainable from previous laboratory tests. When solids are less than about 80 microns, the slurry is usually non-settling. For a non-settling slurry, design flow can theoretically be very low, but energy dictates need to be higher. If laminar, any large particles may settle. Non-settling slurries have a zero flow wall shear stress, both a laminar and turbulent region, and are very concentration dependent. Laboratory tests of any slurry are always necessary, but when only a small sample is available then it is possible to use a rotating viscometer or extrusion rheometer to evaluate the properties.

Settling slurries range in diameter from 100 microns (0.1 mm fine sand) to 5 mm (small gravel), have a minimum head loss, and a critical deposit velocity. The critical velocity can also be ascertained from nomographs developed from previous laboratory test data. Numerical modeling approaches for describing settling slurries use the concept of a stratification ratio and the threshold of turbulent suspension to estimate the total excess friction pressure gradient. Below this threshold of turbulent suspension, the solids are fully stratified. If the mixture velocity is increased, then parts of the solids pass into pseudo-homogeneous suspension.

Georgia Iron Works (GIW) slurry testing laboratory has developed different models for predicting head loss along the pipe based on extensive slurry test over a wide range of parameter values. The GIW models are believed to be the best models available since they are based on precision experimental data of actual materials. It is always important to conduct laboratory tests when the particles vary over a large range of values (Figure 19). The GIW slurry test loops consist of pipe diameters of 3, 4, 6, 8, 12, and 20 in. GIW performed a range of tests for the U.S.

Figure 19. Large range of slurry particle size diameters

Army Corps of Engineers in the 4-in.-diam test facility. Three different sand sizes were evaluated (650, 1,250, and 2,250 microns). Four concentrations of each sand were tested (5, 10, 20, and 30 percent by volume). Five concentrations of clay were tested for each sand (0, 2, 4, 5, and 6 percent by volume). Sixty total tests were performed, and the head losses for different slurry mixtures for a range of velocities were determined. Slurry tests were also conducted for the Hibernia oil platform to determine the head loss characteristics of pumping magnetite ore in various pipelines. Results would be used to design the distribution system. Average solids had a specific gravity of 4.39 with an average particle size of 25 mm. Tests were conducted in the combo 254/305 mm loop at 0, 4, 8, and 16 percent by volume, with flow rates up to 550 liters/sec. Other tests were conducted in the 406/457/508 mm loop at 0, 6, 8, and 10 percent by volume, with flow rates up to 1,250 liters/sec. Then tests were conducted of the full-scale mock-up of the actual distribution system at concentrations of 0, 4, 8, and 12 percent by volume, with flow rates up to 1,800 liters per sec.

The Dallas White Rock Lake project involved the transport of dredged sediment from a lake for 20 miles. Slurry analyses were conducted by GIW using an extrusion rheometer to predict pipeline friction. Here the material was silt, not sand. Sand would have required twice the velocity as the silt, have 3.25 times the friction of the silt, and require 6.5 times the power as the silt. Results of these tests by GIW determined that 3 pumps would be adequate instead of 9 pumps previous estimated. The result was that 5,000 Hp pumps total were used instead of the 27,000 Hp previously believed necessary, and a huge project dollar savings ensued. Actual dredging control operations were conducted with a radio link to the dredge, and phone lines to the remote unmanned boosters.

Figure 20. Dallas White Rock Lake pump

Figure 21. Remote unmanned booster pump, Dallas White Rock Lake

Usually, centrifugal pump operations limit the number of pumps to 6 in a series in any one application. However, for pumping phosphate mine tailings in Florida, GIW laboratory tests (Figure 22) determined that 11 pumps in a series could be located along a 21-in.-diam pipeline pumping for 8.5 miles.

Figure 22. GIW phosphate pump and pipe tests in the field

It is possible to use centrifugal pumps to transport solids in a pipeline up to 30 miles, and much further. It is important to categorize slurries accurately (determine the range of particle sizes in the slurry) to identify the most energy efficient, lowest wear operating velocity and concentration. Because of the many variables encountered in actual sedimentary materials (sands and clays of various sizes), laboratory tests are essential in most cases to determine pipe friction and pump performance characteristics.

James Norwood, Pipeline Systems, Inc., Concord, CA

Mr. Norwood presented "**Long-Distance Solids Transportation by Pipeline Systems, Inc.**" Pipeline Systems Incorporated (PSI) is a specialist in hydraulic solids material transport systems design, construction management, start-up and commissioning, and operations services for worldwide projects involving major slurry pipeline systems using positive-displacement pumps. PSI provides supervisory control and data acquisition design, panel assembly, programming, integration, and installation. PSI offers (a) conceptual and feasibility studies, (b) laboratory testing, (c) route reconnaissance, (d) basic and detailed design, (e) slurry pipeline modeling, (f) capital and operating cost estimating, (g) management of construction, (h) commissioning (pre-operational testing, start-up, performance guarantee tests, and operator training).

Figure 23. PSI-developed pipeline splitter box and dilution system

Unlike most centrifugal pumps, positive-displacement pumps are incorporated by the system designer into the complex machinery package. The positive-displacement pump has an expanding cavity on the suction side and a decreasing cavity on the discharge side. Liquid flows into the pump as the cavity on the suction side expands and the liquid flows out of the discharge as the cavity collapses. This principle applies to all types of positive-displacement pumps,

Figure 24. PSI copper tailings positive-displacement pipeline

whether the pump is a rotary lobe, progressing cavity, rotary gear, piston, etc. A positive-displacement pump, unlike a centrifugal pump, will produce the same flow at a given speed no matter the discharge pressure.

An example of the longest major slurry pipeline systems developed by PSI for transporting different kinds of materials include (a) limestone transport (Rugby, England, 10-in.-diam, 92 km), (b) phosphate concentrate (Vernal, Utah, 10-in.-diam, 153 km), (c) coal transport (Black Mesa, Arizona, 18-in.-diam, 439 km), (d) iron concentrate (Samarco, Brazil, 20-in.-diam, 395 km), (e) copper concentrate (Alumbrera, Argentina, 6-in.-diam, 314 km), and (f) copper tailings (Hokuroku, Japan, 12-in.-diam, 71 km). Thus, pumping 30 miles (50 km) is routinely accomplished with positive displacement pumps.

Figure 25. PSI 48-in.-diam polyurethane-lined pipeline

Many other slurry pipeline systems have been developed by PSI that use much larger diameter pipelines, but those pumping distances were less than distances mentioned above. For example, a 48-in.-diam pipeline was used to pump copper tailings at Kennecott UCD, Utah, for a distance of 48 km (approximately 30 miles). Whereas a centrifugal pump system may convey a mixture of **80 percent water** and **20 percent solids**, a positive-displacement pump system may convey the reverse (i.e., **80 percent solids** and **20 percent water**).

Key system design issues addressed by PSI include (a) optimize slurry properties for long-distance transport, (b) material optimization for corrosion and erosion resistance, (c) "life-of-project" planning for configuration changes, (d) material separation of different grain sizes by cyclone clusters (Figure 26) for construction material acquisition, (e) planning for upset conditions such as power outages, (f) environmental planning for design, construction, and operation), (g) staffing plans for central control, communications, and monitoring, and (h) regulatory regimes.

Figure 26. PSI cyclone clusters for material separation

Gary Scott, EnSenTech Corp., Centerville, UT

Mr. Scott presented "**Long-Distance Pipeline Transport of Materials by using Air Resources Technology**". Air Resources Technology (ART) is designed to handle liquids and solid materials ranging in size from 2 microns up to 3-in.-diam stone. ART systems are presently available to handle capacities ranging from 2 to 600 tons per hour; however, much larger systems with virtually unlimited capacity can be designed and built but are only concepts at present. ART has numerous successfully demonstrations (Figure 27) for handling a wide range of very diverse products and raw materials through its mechanical-pneumatic pumps. The system employs low-pressure (up to 10 psi) air rather than water as the medium of transfer.

Figure 27. ART demonstration site, Tacoma, WA

Because material moves by airflow through the pipeline as a pseudo-homogenous gas, transfer can be accomplished straight up, at angles, and around corners. System components include a large positive-displacement air supply typically driven by a diesel engine for a mobile installation or by an electric motor for a fixed installation. A vortex injection device is able to introduce material into the pump with sufficient velocity to allow the linear accelerator to work in conjunction with the zero velocity boundary layer under laminar flow principles. The ART systems are the most cost-effective systems to build, maintain, and use, but they must be carefully engineered for each application. Systems can be either completely portable or fixed since there is no internal wear to consider. The pipeline may be of the thinnest material available since there is no pipe wall friction, and, thus the pipe is easily transportable. Operations can be either steady or intermittent, and operational distance when transporting material is unlimited with booster pumps.

The ART system configuration (Figure 28) consists of six basic components; (a) a linear accelerator (pump) which collects and impels bulk materials into the system, (b) a blower assembly package that provides the air supply, (c) one or more airlines that carry the air supply to the linear accelerator, (d) a discharge system (air chamber/nose cone assembly) which receives the incoming air stream, (e) product pipelines lines through which bulk materials are transported, and (f) control panels and computer systems which govern operation of the system. In a typical arrangement, several of these components are interfaced with other more conventional apparatus such as crushing chambers, cyclones, classification chambers, velocity drop boxes, and other devices characteristic of a custom designed and integrated materials processing system. The configurations of such devices depend upon (a) distances, (b) capacity volumes, and (c) specific product characteristics.

Figure 28. ART pump and inflow filling system

When blowers are activated, air traveling through the airlines is injected into the system through one or more ports connected to the air chamber/nose cone assembly. Depending upon desired results to be achieved, the air stream is injected with either a linear or rifling affect. The system forms a stable high velocity air flow in the center of the pipeline throughout the length of the pipeline, and surrounds the stable flow with a zero velocity boundary layer of air. The natural characteristics of the vortex thus created tends to draw transported materials toward its center, thus causing the boundary layer to function as an air bearing with very low friction through which material particles are transported.

The ART dredging system uses a submersible dredging head that removes mostly solid materials from underneath the channel bottom; thus fish and other aquatic life would remain undisturbed. If the material will not flow naturally to the system intake, then cutterheads are activated to cause material to flow to the unit. The system pumps minimal water with the slurry consisting of up to **80 percent solids** and **20 percent water**. Delivery wastewater containment is never a major problem due to the low percent water in the pipeline. The thin wall plastic pipeline will float even when full, thereby requiring no support floats. Material dredged and transported by the ART system can be compacted into dikes, landfills, and roads, and can be used to restore degrading coastal marshlands.

Figure 29. ART technology being used to transport coal by pipeline

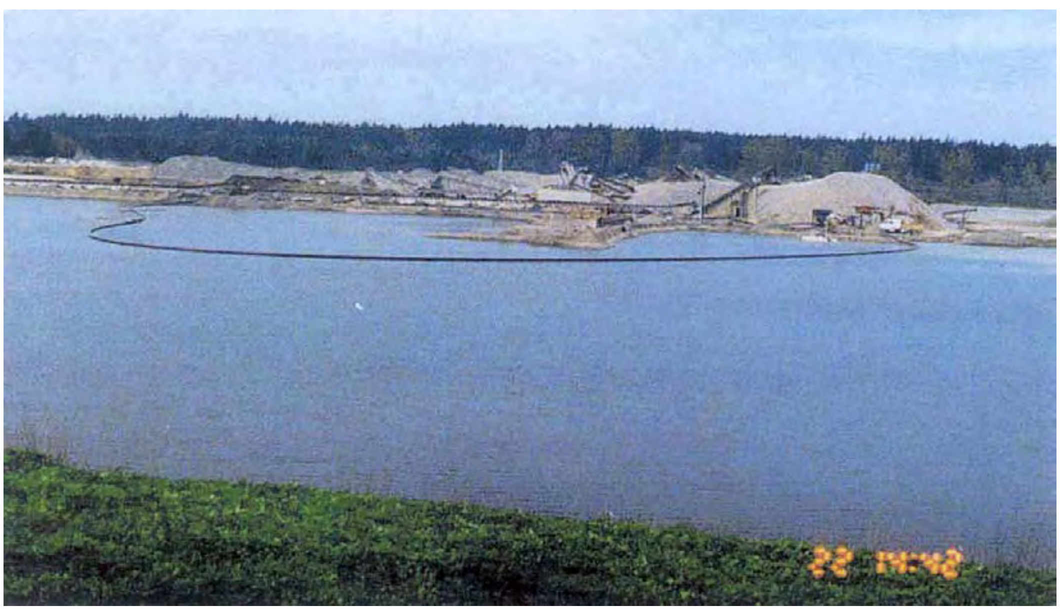

Figure 30. ART dredging system and pipeline transport in operation

Summarizing Panel Discussion: Using Pipeline Transported Materials to Rebuild and Maintain Coastal Marshes; Workshop Conclusions and Next Steps

Denise Reed, Panel Moderator, University of New Orleans, New Orleans, LA
Edmund Russo, U.S. Army Corps of Engineers, New Orleans District, New Orleans, LA
John Ettinger, U.S. Environmental Protection Agency, New Orleans, LA
Richard Smith, Weeks Marine, Inc., Kenner, LA
Lawrence Rozas, U.S. National Oceanic and Atmospheric Administration, Southeast Fisheries Science Center, Lafayette, LA

The Panelist were charged with the mission of describing what they see as the main challenge to using pipeline conveyed sediments to actually recreating and/or nourishing Louisiana marshes. The panelist's consensus, shared by the audience, was that there were no fundamental technological challenges to the delivery of material but that some questions remained concerning placement for specific restoration purposes. Some panelists challenged restoration agencies to come up with specific plans to use pipeline conveyed materials so that these placement issues could be discussed in less abstract terms, and others pointed to the need to explore placement and habitat creation issues through "demonstration projects". The concept of designing a "virtual distributary" using dredge pipes was raised, and the panelists challenged themselves, dredging experts and resource agencies to further explore these ideas.

What are we trying to achieve in the landscape?

Efforts to restore coastal Louisiana are built on some underlying principles, including restoring and/or mimicking the natural processes that originally built and maintained coastal Louisiana. It is generally accepted that sustainable ecosystem will be best restored in coastal Louisiana by utilizing the same natural forces that initially built the landscape and that ecosystem restoration strategies larger in scale than any that have ever been implemented in the past are necessary. However, limited sediment availability and a willingness to expediently produce results in the near-term likely mean that dredged material will be a vital component of restoration success.

Restoration of coastal marshes with dredge material involves consideration of placement modes (e.g., confined, semi-confined, or open water). All involved in restoration recognize that it is equally important to maintain barrier islands, in part due to their potential to reduce tidal forces within marshes, as well as rebuild marshes. New sediment (sediment not currently in the estuarine system or sediment not readily available) should be introduced for restoration purposes. Sediment bedload of the Mississippi River presently being delivered to the Gulf of Mexico is a prime example. Material to build barrier islands should be sand, while material to build wetlands will include sand and smaller diameter material. Great volumes of material will be required to rebuild the barrier islands, and some of that material may of necessity come from offshore borrow areas. The dynamic estuary/barrier island interrelationship implies that smaller bays and more interior wetlands may produce more resilient islands. An erosion-resistant base for barrier islands should be designed to weather extreme events at a critical state as considerable investment return can be derived from increased sediment scour resistance. Dredging restoration of wetlands can be used in concert with diversions to assure continued sustainability of the created habitat and provide dynamic function.

What are the most important technical considerations?

Regardless of the type of transport facility eventually developed, all material for restoring the marshlands of south Louisiana will be dredged, either from the Mississippi River or from offshore sources using either a cutterhead pipeline dredge or hopper dredge. The dredged material may be either single-handled or re-handled. Single-handling involves pumping via pipeline directly to the destination, with or without booster pumps in the line (depending on the pumping distance). If the transport design requires re-handling, the material will be dredged and stockpiled for later transport. Stockpiling will tend to dewater the dredged material, either deliberately or otherwise. After dewatering, the material may be placed in scows and barged to the destination site, or the material may be re-slurried and pumped to the ultimate site, with or without booster pumps in the line (again, depending on the pumping distance). Three fundamentally different material handling mechanisms were discussed at the workshop; (a) centrifugal pumps, (b) positive-displacement pumps, and (c) air injection technology.

Centrifugal pumps: It is possible and feasible at the present time to transport solids in pipelines up to 30 miles, and much further. The Dallas White Rock Lake project involved transport of dredged sediment (silt) from a lake for 20 miles with the use of booster pumps. For that project, laboratory tests performed at Georgia Iron Works (GIW) testing facilities determined that only 3 pumps would be adequate instead of 9 pumps previously estimated, resulting in considerable cost savings. One concept for re-nourishing the south Louisiana marshlands is to pump material from the lower Mississippi River by centrifugal dredge pumps to restore areas on each side of the River. Centrifugal pump transport density has a range of values depending on specific circumstances up to **20 percent solids** and **80 percent water**.

Positive displacement pumps: Unlike most centrifugal pumps, positive-displacement pumps are incorporated by the system designer into complex machinery package. The positive-displacement pump has an expanding cavity on the suction side and a decreasing cavity on the discharge side. Liquid flows into the pump as the cavity on the suction side expands, and the liquid flows out of the discharge as the cavity collapses. A positive-displacement pump, unlike a centrifugal pump, will produce the same flow at a given speed no matter the discharge pressure. Pipeline Systems Incorporated (PSI) has designed numerous positive-displacement pump systems for hydraulic solids material transport for a range of pipe diameters, including 18-in.-diam up to 250 miles and 48-in.-diam up to 30 miles. All these "life-of-project" designs were developed through laboratory testing facilities. Positive-displacement transport density has a range of values depending on specific circumstances up to **80 percent solids** and **20 percent water**.

Air injection technology: Air Resources Technology (ART), developed by EnSenTech Corporation**,** is designed to handle liquids and solid materials ranging in size from 2 microns up to 3-in.-diam stone. ART systems are presently available to handle capacities ranging from 2 to 600 tons per hour; however, much larger systems with virtually unlimited capacity can be designed and built but are only concepts at present. ART has numerous successfully demonstrations for handling a wide range of very diverse products and raw materials through its mechanical-pneumatic pumps. The system employs low-pressure (up to 10 psi) air rather than water as the medium of transfer. Material is moved by airflow through the pipeline as a pseudo-homogenous gas. System components include a large positive-displacement air supply. The ART dredging system uses a submersible dredging head that removes mostly solid materials from underneath the channel bottom; thus fish and other aquatic life would remain undisturbed. If the material will not flow naturally to the system intake, then cutterheads are activated to cause material to flow to the unit. The system pumps minimal water with the slurry consisting of up to **80 percent solids** and **20 percent water**.

Abandoned pipelines

The use of formerly-used (abandoned or quasi-abandoned) pipelines as a means of transporting material to the marsh was discussed. The system of pipelines is statewide, interconnected, and of high density in wetlands and along the coast. However, most unused pipelines may not be legally abandoned. Abandoning a pipeline eliminates removal impacts and associated costs, but also entails legal ramifications. While use of existing right-of-ways for formerly-used pipelines to construct a new system of pipelines for long-distance transport of dredged material to restore coastal Louisiana may indeed be feasible, it was the opinion of the panel that formerly-used pipelines themselves are probably not appropriate for dredged material conveyance due to dimensional constraints, inappropriate or restrictive locations, and concerns regarding structural soundness. Thus, the panel agreed that utilization of formerly-used pipelines not be further considered.

Opportunities and next steps

It was noted that actual distribution and placement of material after transport had only been peripherally discussed at this workshop. Restoration is a 3-step process: (1) ascertaining a source of material, (2) optimizing the transport mechanism for getting that material to the appropriate location, and (3) distribution and placement of the material at the desired location. The sponsoring organization (EPA) made a considered decision that this initial workshop should concentrate only on steps 1 and 2. If a source of material is not available, or if a source is available but it's characteristics are not compatible with existing marshland materials, then steps 2 and 3 are meaningless. If step 1 is feasible but step 2 is deemed to be infeasible or otherwise not practical, then step 3 would be moot. Conversely, if steps 1 and 2 are both determined to be practical, then one or more workshops may be necessary for analyzing ramifications associated with distribution and ultimate placement, including design features and elevations of the marshland with respect to plant and animal colonization as well as the mechanical attributes of physically placing the material to the right configuration.

It is clear that the technology to transport materials via pipeline over long distance has been in use for a long time, with success in a variety of locations and with a variety of challenging materials. The panel suggested that it is now important to review potential sources of external sediments and discuss methods of placement of transported sediments. This could include considerations of synergies among restoration projects using dredged material and those diverting river water and sediments.

It is absolutely essential also to consider the importance of designing and constructing ecologically functional marshes with dredged material. Dredged material has been used for decades in beneficial use projects to construct tidal marshes, and the objectives of these restoration projects often include support for fishery species. However, the design of these constructed marshes frequently does not take into consideration the habitat needs of target organisms, and consequently, the created wetlands provide little support for fishery species. A concept for designing restoration projects that should be explored is using long-distance pumping of dredged material as part of a project to mimic river delta building processes.

The need to discuss such plans to use pipeline conveyed materials in less abstract terms was clear. Such discussion could lead to the development of more detailed concept proposals for "demonstration projects" to clarify issues regarding material placement or rebuilding a "virtual distributary".